COMPUTER ANIMATION AND VIRTUAL WORLDS
Comp. Anim. Virtual Worlds 2016; **27**:58–71
Published online 9 April 2015 in Wiley Online Library (wileyonlinelibrary.com). DOI: 10.1002/cav.1631

RESEARCH ARTICLE

Perceptual validity in animation of human motion

S. Ali Etemad[1]*, Ali Arya[2], Avi Parush[3] and Steve DiPaola[4]

[1] Department of Systems and Computer Engineering, Carleton University, Ottawa, ON, Canada
[2] School of Information Technology, Carleton University, Ottawa, ON, Canada
[3] Department of Psychology, Carleton University, Ottawa, ON, Canada
[4] School of Interactive Arts and Technology, Simon Fraser University, Surrey, BC, Canada

ABSTRACT

The crucial concept of modeling and synthesis/control of human motion (including face and body) for animation has been widely studied and explored in the literature. In this regard, the audience's perception of generated or recorded animation scenes is of critical importance. In this paper, we explore and conceptualize the general notions that need to be taken into account for human motion to maintain perceptual accuracy. We propose a paradigm called Perceptual Validity composed of four major components, which are discussed in detail. The model is concerned with different aspects of the scene such as correct illustration of the stimuli, context, and local/global relations of various visual cues present in human motion. Satisfying all the proposed principles, based on the literature, seems compulsory and vital for synthesis of perceptually valid animation scenes of human motion. We investigate the relative significance of the different components of the paradigm using feedback from expert animators and conduct a case study on one of the components of the paradigm. For further evaluation and exploration, Disney's principles of animation are discussed and compared against our proposed paradigm. We argue that while there are significant parallels and overlaps, our model is only focused on and more inclusive towards human motion and can therefore provide a valuable set of guidelines for animators in the field of character animation.

KEYWORDS
animation; motion; perception; body; face; perceptual validity

***Correspondence**
S. Ali Etemad, Department of Systems and Computer Engineering, Carleton University, Ottawa, Canada.
E-mail: ali.etemad@carleton.ca

1. INTRODUCTION

Human motion studies are currently drawing much deserved attention. This is due to the advancements in computing capabilities, which have lead to a significant growth in applications such as animated movies, interactive games, interactive gesture-based everyday applications, and virtual worlds that use character motion and animation as a key component.

Generally, human motion can be considered as a combination of two sets of themes represented by corresponding features [1]. While the primary themes (PTs) specify actions like walking or running, the secondary themes (STs) relate to affect, style, or individual characteristics in which those actions are performed. These stylistic variations, or secondary features (SFs), are constantly present in motion data and have been noticed by researchers as early as Darwin [2]. In multimedia content, different characters, based on their roles and attributes, display different types of STs in motion.

In the literature, a variety of methods has been proposed for processing both primary and STs in motion. These methods range from rule-based [3] to complex machine learning methods [4]. Nevertheless, a critical question that needs a careful consideration is the following: what components and factors need to be taken into account when adding or altering different features (primary or secondary) in motion? In other words, what should be the motivating factors for processing motion features, and what are their relative degrees of significance?

In this paper, we aim to provide a general set of guidelines that address the aforementioned questions. Accordingly, we first suggest that as multimedia content (including those containing motion animation) are intended for human audiences, our perception of the depicted animation scenes is of critical importance. Furthermore, we review various factors that influence how audiences receive and approve animation content. We then propose a general paradigm called perceptual validity (PV). PV is a model based on the parameters that impact our perception of motion and aims at believability, acceptability, and perceptual (not necessarily format related) attractiveness of the animated characters. Our PV paradigm associates various visual cues to viewers' perception according to the literature and a set of experiments and establishes principles to help animators create content that is perceived as intended. The PV principles, which we propose, are particularly important as they can be used as the foundation of intelligent algorithms for procedural generation of believable character animation. The proposed paradigm consists of four different components. Each component is described with tangible examples. A case study is carried out on one of the components. We refrained from performing case studies on all of the components as they are mostly self-evident or backed up by the literature. Subsequently, a study is performed that describes the relative importance of each of the components and underlying elements. Finally, we compare and discuss our paradigm against Disney's 12 principles of animation [5].

2. WHAT MATTERS IN CHARACTER ANIMATION?

A variety of different factors impact how audiences feel towards a presented animation clip. These factors include format-related ones such as frame rate, resolution, and noise to content-related ones such as camera, light, story, characters, and music. A variety of different parameters influence character animation, among which, this paper is concerned with motion, which in turn can be divided into two major segments: face motion (FM) and body motion (BM). This taxonomy is presented in Figure 1.

John Lasseter of Pixar (http://www.pixar.com) has said: "When character animation is successful and the audience is thoroughly entertained, it is because the characters and the story have become more important and apparent than the technique that went into the animation. Whether drawn by hand or computer, the success of character animation lies in the personality of the characters" [6]. Personality or personal characteristics of digital characters are derived from a variety of factors that can be categorized together as part of STs. STs can include emotions, gender, age, energy, and even attributes such as health, genetics, and social aspects, and others. Accordingly, interpretation and synthesis of the features that display these themes is of critical importance. For example, in an animated film or a virtual world, a female character should walk differently compared with a male character. As another example, in a computer game, based on the energy level and health of a character, different styles of actions need to be displayed (tired, energetic, healthy, injured, etc). In all these cases, it is important that the viewer perceive the action the way it was intended both in terms of PTs (what is being done) and the secondary ones (who is doing it, and how). This means that the motion does not only need to be physically or functionally correct but also perceptually valid.

Chuck Jones, the famous animator of Warner Brothers (http://www.warnerbros.com), has said: "Believability. That is what we were striving for" [7]. Ollie Johnston and Frank Thomas, from Disney Studio's so-called "Nine Old Men" in their book *The Illusion of Life*, state that: "Disney animation makes audience really believe in characters. There is a special ingredient in our type of animation that produces drawing that appear to think and make decisions and act on their own volition; it is what creates the illusion of life" [5]. Believable characters demonstrate believable behavior, which stems not only from physical realism but also from the audiences' perception of displayed content and form a major component of quality in animated content.

Other traits have been associated with quality and appeal in motion pictures, especially that of computer-generated nature. From one standpoint, the notion of high-quality content can be associated with the concept of esthetics. The concept of esthetics or beauty itself, however, is philosophically subjective and somewhat vague. As David Hume puts it in 1742, "beauty in things exists merely in the mind which contemplates them" [8]. Esthetics experts, artists, and psychologists have offered many theories of what makes people consider an object beautiful, from evolutionary explanations to spiritual bases [9]. Some have associated this notion with the existence of expressive details and edits [10–12]. Furthermore, it has been illustrated that different factors such as generation of special effect scenes [13] and cinematic narrative discourse [14] play critical roles in synthesizing appealing multimedia content. Others have related beauty in art to the concept of creativity, and as a result, dynamic content generation [15,16].

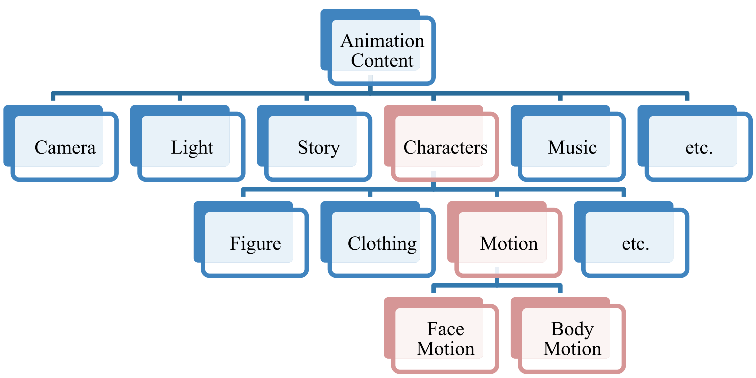


Figure 1. Parameters that influence animation content quality.

DOI: 10.1002/cav

From another point of view, satisfaction and appeal may arise from being in one's comfort zone. Thus, some researchers have associated satisfaction (particularly in computer games) with exposure to specifically preferred content [17,18]. Credibility and trust towards characters is another critical concept, which has been directly or indirectly linked to believability and realism [19]. Naturalness of motion is another perspective from which appeal can be discussed. "Natural" phenomena are constantly occurring around us, and as a result, we become accustomed to them. Therefore, our perception of events and the concept naturalness are highly correlated [20–22].

Generally, visual and physical components of the scene often play an inferior role to perceptual factors [23]. It has been shown that noisy and inaccurate animation may be preferred over robotic and bland, yet accurate motion [24]. Researchers have explored visual obscurities in animation (e.g., length of objects), and determined boundaries within which physical errors can go unnoticed [25], let alone diminish the perceptual experience of the audience. In fact, independent of physical validity, stylized editing such as "squash and stretch," which we discuss in the Discussion section of this paper in the context of human motion, are shown to increase prediction accuracy, attention, and appeal towards the content [26], rather than the opposite that can be expected because of supposed physical inaccuracies or exaggerations.

In animation (or any other phenomenon), although it is incredibly difficult if not impossible, to quantify or conceptualize many of the previous concepts, we believe the human perception of the different aspects of displayed content can provide a decisive framework for assessment. Whether we ground these frameworks on esthetics/beauty, naturalness, or believability, as these notions are all subjective to the perception of the audience, it is ultimately our perception of details that determines the validity of the presented content.

3. BODY AND FACE MOTION

While some studies were carried out on human motion between 1953 and 1970 [27–31], it was Johansson who, in 1973, initiated the modern study of human motion perception [32]. By attaching small light sources to different body joints, and showing that naïve participants could rapidly recognize the motion of such orientation of lights (filmed in a dark room) as a human structure, the method of point light (PL) motion representation was introduced. The potential for the PL model in psychological and behavioral studies was quickly realized and its introduction helped with a variety of more detailed studies on biological motion. The course of human motion studies has since expanded through a wide range of hypotheses and findings. Spatiotemporal properties and variations of Johansson's model have been widely explored [33–35]. Perception of gender [33,36–38], identity [39,40], and affect [41–45] from motion has been demonstrated. The affect of different geometrical models such as a stick figure and polygonal figure on motion perception has been investigated [46,47]. Perception of attributes such as affect and energy from motion of specific limbs [43,48,49] has also been shown. For a comprehensive review on the subject, the reader is referred to [50,51].

Computational processes on human motion that aim at interpretation [52] or synthesis [4] of features have also been widely explored. The former category of systems utilize pre-existing recordings such as videos or motion capture data to extract information regarding the classes of actions and STs, retrieve and segment videos, and more, while the latter aim at controlling [53], editing [54], or generating actions or motion features (including SFs) [4] for animation purposes.

The human face is also known to convey a rich amount of ST-related information [55]. As a result, a considerable amount of research has been performed on creating personality-rich facial animation. Facial action coding system was one of the first systematic efforts to determine the smallest possible facial actions, or action units, and associate them to facial expressions [56]. Associating facial actions with personality requires a reasonably adequate personality model for the agent and a thorough study of the effect of facial actions on the perception of personality. The latter, has not been carried out properly yet, but the former has been the subject of some recent works. A multi-layer personality model has been proposed [57], which is, more precisely, a multi-layer behavioral model that includes layers of personality, mood, and emotions on top of each other. Every layer controls the one below it, and the facial actions and expressions are at the bottom. The model allows element of parameters at each level to individualize the agent. At the personality level, it utilizes the Big Five model with five parameters. Following observations can be made regarding this system:

- The problems associated with using the Big Five such as difficulty in visualization and correlation between dimensions.
- Hierarchical dependence of personality and emotional states.

It has, in fact, been suggested that these should be treated independently [58]. Other proposed models follow similar notions [59,60]. The latter uses a two-dimensional (2D) model similar to the one proposed in [61] for personality (called performatives) and also separates them from emotions as two independent components activating facial actions through a belief network. This 2D model has been used to associate facial actions to personality dimensions, dominance and affiliation [62].

The location of common emotional states in a circumplex in 2D space with arousal and valence (activation and pleasantness) as the dimensions has been defined [63] and presented in Figure 2. This model has also been used for affective states through BM. Control was later

DOI: 10.1002/cav

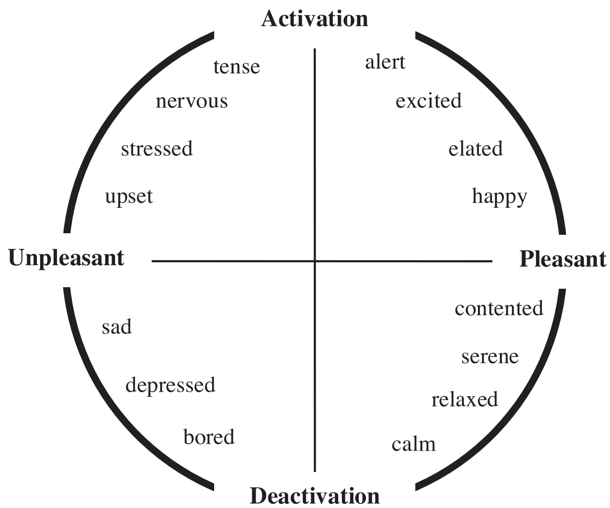


Figure 2. Model of emotions [63].

suggested as the third parameter [64] while uncertainty and agency have been proposed in [65,66]. The significant visual cues that can be considered more important perceptual factors in animation have been studied in [67]. Finally, the temporal effects and also the issue of conflicting signals have been reviewed in [68].

4. PROPOSED PARADIGM

The proposed paradigm is called PV because we believe abiding by the elements that it puts forth will ensure the perceptual quality of human motion animation. The paradigm takes into account PTs and STs in both FM and BM domains. Furthermore, the context in which the animation is presented is taken into account. The paradigm proposes four major components: association, contextual dependency, internal consistency, and external consistency, each of which is composed of several elements. Following the different components and elements are described accompanied with examples.

4.1. Association

Whether for FM or BM, for both PTs and STs, it is imperative to display the correct visual cues based on the intentions of the animators. Therefore, the first step towards synthesizing a perceptually sound sequence of human motion is to recognize the set of visual cues (features), which will generate each possible PT/ST based on the requirements of the scene. The fashion in which the stimulus is visualized and displayed can significantly impact the two themes as perceived by the audience. We call the correct presentation and preservation of visual cues, association. In other words, association dictates that the visual motion cues displayed by the characters comply with the intentions of the animators in terms of PTs and STs.

While PTs are quite intuitive because of the effect in which different actions result in, the STs are not that simple to artificially generate or identify. In fact, there have been many publications on the visual cues responsible for perception of different STs for both FM and BM. The visual cues corresponding to Ekman's basic set of emotions [69] (as an accepted example for a subset of STs) for both FM and BM can be utilized. Examples of these visual cues are available in [70,71].

In addition to correct utilization of visual cues, it is essential that the stimuli be presented such that the intended themes are not perceived differently. Preservation of the stimuli must occur both temporally and spatially. It is well known and demonstrated that spatial and/or temporal alterations in visual cues for both FM and BM will affect the perceived STs [72].

Another implication of this rule is that extra movements, such as those responsible for creating the famous foot-skate artifact [73] or tremor in the motion, must not appear in the motion. This is due to the fact that such movements in joints and other body parts might alter the present primary or SFs or make them undetectable to the untrained eye.

4.1.1. Examples.

It has been shown that face inversion results in difficulties in its recognition [74] and distorts the perception of its features [75]. More particularly for effects of spatiotemporal alterations on face stimuli, it has been displayed that inversion of face stimuli reduces the accuracy emotion recognitions such as fear, anger, and disgust, and even results in sadness being identified as neutral by the audience [76]. Similar trends regarding importance of spatiotemporal preservations have been observed for BM stimuli in which PL walkers are often used for perceptual studies. It has been shown that 1.6–2.7 s of motion are required for correct gender recognition of a walker [33]. Moreover, when stimuli are inverted, the gender is often recognized as the opposite, meaning for upside down presentation of the PL walker videos, a male walker is more likely to be recognized as female and vice versa [33]. In another study, it was indicated that when hip movement is greater than the shoulder movement, the sequence appears as feminine to untrained eyes and vice versa [77,78]. It was later shown that this "extra movement" is rather velocity than displacement [37]. This shows the necessity for temporal preservation of the stimuli. The aforementioned findings and many other similar investigations signify the importance of proper stimuli presentation.

4.2. Contextual Dependency

Performance and perception of PTs and STs performed by characters are heavily linked to the theme of the scene or the context [79–81]. Accordingly, It is safe to claim that the audience does not expect to see behaviors that contradict or are out of context. While in terms of physics of human behavior, such inconsistencies are possible; the typical audience would not expect to experience such scenes or, at the very least, would consider it to be odd. Consequently, the second factor that we believe is essential in PV is contextual dependency. This component of the paradigm indicates that both primary and STs for both body and FM depend on and need to be consistent with the context of the scene. It should be noted that the need for contextual dependency is present for both themes. Some PTs are simply not acceptable with certain contexts, and some may have global or cultural implications making them unacceptable at given scenarios. Also, for STs, the audience expects contextual reasons for expressive behaviors.

A point to consider in this regard is that contextual dependency is local with respect to the character. This means that for each character in the scene, the context might differ based on the story, background, and agenda. Therefore, context only refers to the perspective of the character of interest. Should several characters be present in the scene, each will have his/her own local context.

4.2.1. Examples.

An audience expects to see running, walking, jumping, and dribbling as primary actions of players during a basketball game. Displaying actions of, for example, dancing is therefore unexpected and improper, unless the local context validates the actions. An example of this local context could be a scene of goal celebration. For an example of contextual dependency for STs, we could mention that it is unorthodox to see a happy walk at a funeral, and such a scene will cause perceptual disbelief and distaste. Again, similar to PTs, local contexts can validate apparent dissociations.

4.3. Internal Consistency

A component of PV, which we call internal consistency, refers to PTs of the character being consistent with one another, while a similar consistency exists for STs. As both FM and BM domains need to be taken into account, many different scenarios can be considered. Namely, consistency needs to apply to the PTs of BM, the PTs of the FM, the STs of BM, and the STs of FM. Moreover, cross-internal-relations of FM and BM must be considered. This means that PTs of BM need to be in line with the PTs of FM, and the STs of BM need to be consistent with the STs of FM. Models such as Russel's circumplex [63], as described earlier, can provide valuable guidelines for utilization of consistent STs in characters.

It should be noted that the term "consistency" is somewhat subjective. As a result, enforcing this component of the paradigm (along with the next one, which also uses the notion of consistency) can be subjective and difficult to materialize. Nevertheless, visual perception is by nature subjective [82,83]. Therefore, as with many other aspects of animation, the judgment of the animators is imperative. Furthermore, other proposed guidelines for animation, for example Disney's principles of animation [5], also contain a considerable amount of subjectivity.

4.3.1. Examples.

A viewer would not expect to see a person playing a guitar and kicking a soccer ball at the same time (internal correspondence for PTs). An example for internal consistency of STs, this time for FM, is that one would not expect to see the eyebrows squeezed and pressed together with anger and frustration while lips and cheeks display features associated with happiness, for example being raised.

4.4. External Consistency

In addition to internal consistency, the two themes, PT and ST, must be consistent with each other. This constitutes the final component for PV, which we call external consistency. Accordingly, PTs and STs in FM as well as PTs and STs in BM need to be consistent. Another implication of this component is cross-external-relations for FM and BM. In other words, in addition to the mentioned rule, PTs of FM need to be consistent with the STs of the BM while the STs of FM are consistent with the PTs of BM.

4.4.1. Examples.

One would not expect to see a character jumping up and down when feeling sad or depressed and showing signs of such emotions. On the other hand, fast and energetic actions are more expected when dealing with STs such as excitement, happiness, or anxiety. Similar expectations are present for facial actions and expressions.

4.5. Summary

Table I presents the detailed statements of the paradigm. We observe that the model contains four major components. Association, contextual dependency, and external consistency are each composed of four elements, while internal consistency consists of six elements. Together, these 18 elements form our proposed paradigm. Figure 3 illustrates a graphical representation of the proposed paradigm in which the arrows symbolize the notion of correspondence/consistency.

5. EXPERIMENTS AND RESULTS

In this section, we report a study aimed at determining the relative significance of the different components and elements presented in Table I. Several participants were asked for their opinions on the topic. As we believe that it is essential to incorporate the opinions of animation experts, half of the participants were selected with experience in motion animation. A case study is performed on contextual dependency through a set of experiments in both FM and BM domains. We selected this component of the paradigm for the case study because it is less self-evident (compared with internal consistency for example). Furthermore, there are also less supporting related work for this component.

5.1. Relative Significance

We believe it is important to determine the relative significance of each of the components and elements of the paradigm in both face and body domains. Twenty-two participants were asked to provide ratings regarding the importance and impact of each element on a 10-point Likert scale. Detailed description of each of the elements in Table I in addition to supporting examples were read for the participants. Initially, definitions and examples of the terms: bodily actions (PT_{BM}), bodily expressions (ST_{BM}), facial actions (PT_{FM}), facial expressions (ST_{FM}), and context were provided. Then, the descriptions and examples of the elements of the paradigm as described in Sections 4.1–4.4 were read to the participants. Eleven of the participants were experienced with animation of human motion, which we call expert participants, and 11 were inexperienced towards animation of human motion. The expert participants had a mean age of $M = 25.8$ and standard error $(SE) = 4.2$. They were either employees of animation studios or graduate students with experience in the field of animation; nine of whom were males and two were females. The naïve participants had a mean age of $M = 30.8$ and $SE = 12.7$; seven of whom were males and four were females. The necessary ethics approval was secured. No compensation was provided for the participants' time.

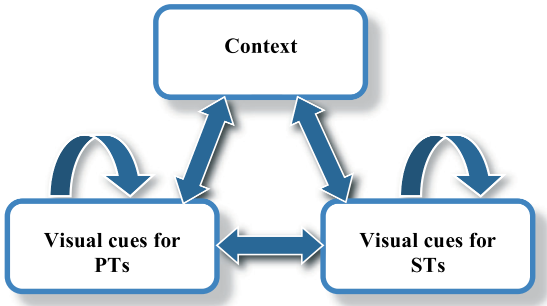


Figure 3. Graphical representation for the concept of perceptual validity.

Figure 4 illustrates the mean and SEs of both expert and naïve participants for each of the PV elements mentioned in Table I. The two important points that should be considered in this figure are expert participants alone and the expert and naïve participants together. In both

Table I. Components and elements of the proposed paradigm.

Number	Component	Element
1	Association	Proper display of PT_{BM}
2		Proper display of PT_{FM}
3		Proper display of ST_{BM}
4		Proper display of ST_{FM}
5	Contextual dependency	Dependence: PT_{BM} and *context*
6		Dependence: PT_{FM} and *context*
7		Dependence: ST_{BM} and *context*
8		Dependence: ST_{FM} and *context*
9	Internal consistency	Consistence: PT_{BM} and PT_{BM}
10		Consistence: PT_{FM} and PT_{FM}
11		Consistence: ST_{BM} and ST_{BM}
12		Consistence: ST_{FM} and ST_{FM}
13		Consistence: PT_{BM} and PT_{FM}
14		Consistence: ST_{BM} and ST_{FM}
15	External Consistency	Consistence: PT_{FM} and ST_{FM}
16		Consistence: PT_{BM} and ST_{BM}
17		Consistence: PT_{FM} and ST_{BM}
18		Consistence: PT_{BM} and ST_{FM}

DOI: 10.1002/cav

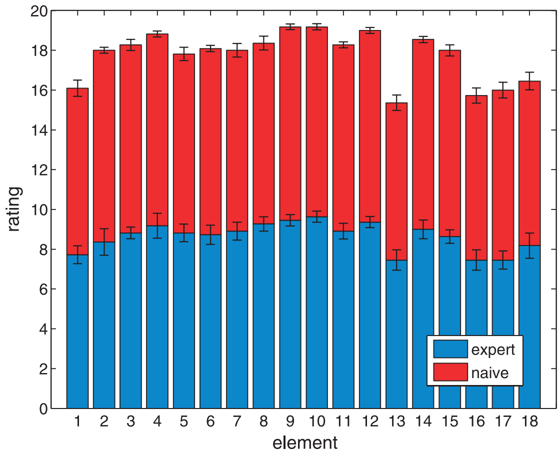


Figure 4. Mean and standard errors of the ratings provided by expert and naïve participants for each element of Table I.

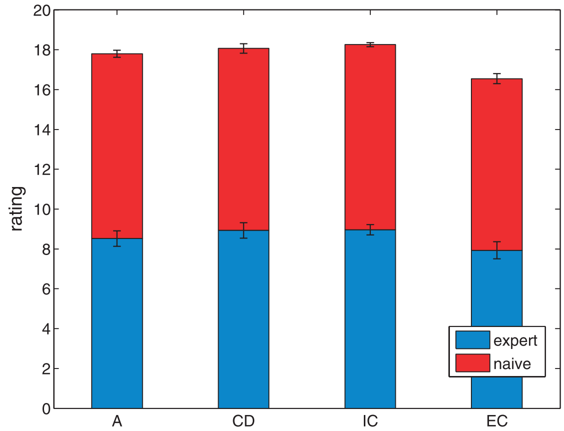


Figure 5. Mean and standard errors of the ratings of expert and naïve participants for each component of the paradigm. Components are in the order presented in Table I.

cases, consistence of PTs between body and face has been perceived as the least importance. Interestingly, the most important element as perceived by expert participants is the internal consistency of PTs for FM, while the naïve participants perceive consistence of PTs in the body as the most important. Internal consistency of STs in the face as well as proper display of SFs in the face have also been perceived as very important by both experts and naïve participants.

One-way analysis of variances (ANOVA) for the ratings of the 18 elements of the paradigm shows that for expert participants, there is significant effect at $p < 0.005$ ($F(17{,}197) = 2.42$). Similarly for the naïve participants, the element poses a significant effect at $p < 0.0001$ ($F(17{,}197) = 3.95$). For the two groups of participants together, similar significant effect is observed at $p < 0.0001$ with $F(17{,}395) = 5.17$.

To further evaluate the relative significance of the four components, we averaged the elements for each of the main components of PV. Figure 5 illustrates the average and SEs of the results for the two participant groups.

One-way ANOVA indicates neither expert nor naïve participants perceive a components to be significantly different ($F(3{,}43) = 1.7$, $p = 0.183$ for expert and $F(3{,}43) = 2.45$, $p = 0.077$ for naïve). However, one-way ANOVA on both ratings together indicates that the two groups together do perceive a significant difference at the $p < 0.05$ level with $F(3{,}87) = 3.34$. Both experts and all participants perceive external consistency as the least important, while internal consistency is perceived as the most significant.

5.2. Case Study

The goal of this section is to provide a case study, validating the concept of contextual dependency for both FM and BM. The stimuli for the FM experiments were created using iFACE, a three-dimensional (3D) facial animation software, developed by Arya and DiPaola [84]. The BM stimuli were from the Carleton dataset described in Appendix A. Alterations to the BM data, where needed, were applied in MATLAB (MathWorks Inc., Natick, MA, USA), and the data were shown in a combinational PL and stick-figure form. A total of 23 naïve participants, 14 males and 9 females, with a mean age of $M = 21.6$ and $SE = 4.0$ took part in this experiment. The necessary ethics approval was secured. No compensation was provided for the participants' time. A set of descriptions regarding the context of the scene was provided to the participants. The stimuli were then presented on a 14.6 in. liquid-crystal display laptop screen, and participants were asked to rate the validity of animation to represent the context provided on a 10-point Likert scale.

Two sets of experiments were carried out, one for FM and one for BM. Each experiment consisted of three cases: case 1 dealt with slight primary actions and neutral STs, case 2 investigated the effect of unexpected primary actions, and case 3 was regarding the effect of unexpected STs in the animation.

In experiment 1, the scenario illustrated a travel agent describing different flight schedules for a vacation to a tropical resort to a costumer. The costumer was happy with the offers and planning to take the trip. Then, three sets of stimuli were presented to the participants, all belonging to a white female agent. In the first case, the agent did not show any particular facial actions or expressions (neutral), only mild nodding occurred. The second case showed fast single eyebrow rises and no particular expressions. Finally, in the third case expressions of sadness were displayed. Figure 6 illustrates these facial expressions.

In experiment 2, it was described that the same agent from experiment 1 printed the ticket (after being purchased by the costumer) and walked to the printer in the other side of the room to pick it up. Case 1 of this experiment showed a neutral female walk, while in case 2, a regular female walk was presented during which the agent threw random punches in the air, and in case 3, a tired female walk was

Figure 6. Snapshots from experiment 1 performed to test contextual dependency: (a) presents a neutral face, (b) is captured from case 1 showing neutral face with slight nodding, (c) is captured from case 2, illustrating fast single rising of a eyebrow, and (d) from case 3, showing expressions of sadness.

presented. Figure 7 illustrates frames from the walking stimuli.

The results of the experiments are illustrated in Figure 8 where the mean ratings are displayed, and error bars represent the SEs. One-way ANOVA shows that there was a significant effect for contextual dependency in FM domain at the $p < 0.001$ level ($F(2,66) = 48.9$). A similar effect was observed in BM domain at $p < 0.001$ ($F(2,66) = 61.28$). It is generally observed that for case 1, where contextual dependency has been taken into consideration, in both FM and BM domains, approval rates are quite high. For case 2 where dependency has been disregarded for the PT, ratings drop in both domains. For BM, however, the drop rate is slightly higher than FM. Similarly, in case 3, where dependency has been disregarded for the ST, the ratings drop in both domains. The drop rate for case 3 in general is less than that of case 2. Also, a higher drop is observed for FM.

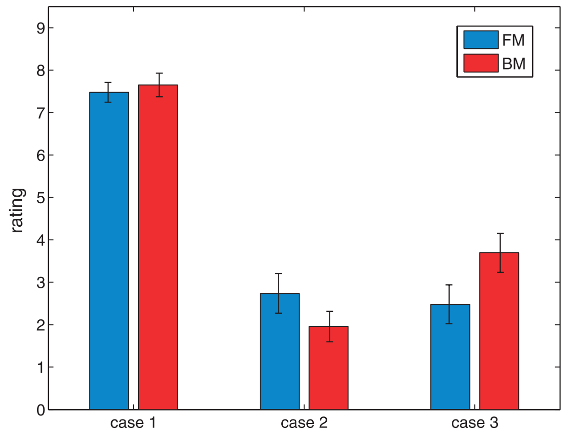


Figure 8. Mean ratings and standard errors for contextual dependency experiments in face motion and body motion domain. Case 1 represents full dependency, while in case 2, the component has not been considered for the primary theme, and in case 3, the component has not been considered for the secondary theme.

6. DISCUSSION

6.1. Relative Significance

The study on the relative impacts of the elements of our proposed paradigm showed that as expected, different elements and components maintain different significance levels, the most important of which (according to expert participants) is consistency between PFs in FM. Moreover, consistency of SFs in FM and proper display (association) of SFs in FM have received higher ratings with respect to others. This is in accordance to earlier studies emphasizing the significant impact of facial features [85]. Moreover, it is interestingly observed that the least important element is internal consistency between PFs of FM and BM, while the importance of internal consistency between SFs of FM and BM is quite high. This indicates that the face and body can perform independently in terms of actions but not emotions and expressions. In addition, proper display of PFs in BM is not perceived as significantly important (compared with that of SFs), which points to proper display of SFs being generally more important. This could be due to the fact that SFs, by nature, are spatiotemporally smaller compared with PFs, and slightest alterations can change the expression, while for primary actions, there is more room for variation (spatiotemporally). In other words, the perceptual message of PFs can be conveyed even when they are not visually sound while the same cannot be said about SFs. Finally, internal consistency is perceived as the most important component while having the least important element, namely, consistence of the PF of BM with PF of

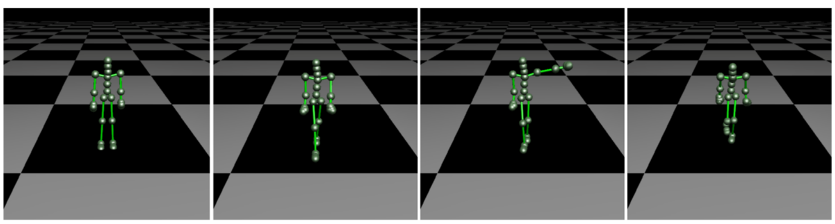


Figure 7. Snapshots from experiment 2 performed to test contextual dependency: (a) presents a neutral stance, (b) is captured from case 1 showing neutral walk, (c) is captured from case 2, illustrating fast normal walk and sudden punches on the way, and (d) is from case 3, showing a very tired walk.

FM. This indicates that aside from consistence of PFs for FM and BM, other elements of this component are very vital in character animation.

The 11 experts, when exposed to the paradigm and asked about its potential applications for animators, provided an average 8.3/10 approval rating with $SE = 1.5$. This indicates that the model as a whole is perceived to be useful and helpful by people with experience in animation of human motion. The animators have generally felt that the paradigm along with its ranking of elements and components can provide a valuable set of guidelines on when and how to modify and process motion animation.

6.2. Case Study

In order to perform case studies on all of the elements of the paradigm, numerous experiments would be required. In this paper, we performed a case study in support of contextual dependency. Association has been widely studied in the literature, and the two consistency laws are quite intuitive and self evident. Our experiments in both FM and BM domains illustrated significant effect for contextual dependency. This means in both FM and BM, and for both PT and ST, disregarding contextual dependency significantly reduced the validity of the sequences for the participants. The FM and BM ratings in each case were not statistically different from one another at the $p < 0.05$ level. The consistency across FM and BM domains are an indicator of the validity of our paradigm and case study. However, there are slight differences in the two domains that need to be discussed. Our analysis of these differences is as follows. In case 1, where the original sequences were displayed, BM shows higher ratings. This can be due to the fact that the BM stimuli were acquired using a motion capture system, while the FM stimuli were synthesized using artificial computer graphic techniques. In case 2, where unexpected primary actions were displayed, ratings for both FM and BM significantly dropped. This is quite expected based on the model and follows the proposed paradigm. Unexpected movements with no particular explanation for the actions reduce the validity significantly. Written feedback by the participants showed that some sort of reason for punching or sudden eyebrow raise must be provided in order for the sequences to be valid. Display of excess movements for BM, on the other hand, reduced the validity slightly more than FM. This can be due to many reasons, but written feedback by the participants provided an interesting insight into this trend. Most participants who, in case 2, provided higher ratings for BM, associated the sudden eyebrow raising of the FM stimuli to some sort of nervous tick. This contradicts the findings of the comparative impact study (where PTs of FM are perceived as more important), but it should be noted that the difference between corresponding elements in Figure 4 are not significant. In case 3 where unexplained secondary actions were displayed, the FM ratings almost stayed the same (compared with case 2). Therefore, a sad face, according to most participants, is not at all valid when applied to a travel agent about to sell a ticket. The BM ratings, however, showed an approximate 16% increase in validity. Written feedback from participants related this increase to the probability of the agent being tired from a long working day (or being old in some cases). STs of FM, being more important than STs of BM, is in accordance with the comparative impact study.

An important point to consider is that when creating synthetic animation content, the animator might intentionally disregard some aspects of PV because of the implementation of a particular style, a specific agenda, or role of that animated character. In such cases, one should not expect to precisely witness the estimated impacts of the elements of the proposed model.

In this experiment, the choice of examples might have had an impact on the ratings. Nonetheless, we tried to choose examples that had no commonality with the paradigm component in question. Accordingly, other examples with such little commonality are expected to result in similar, but perhaps not identical, outcomes. It should also be noted that this case study was not performed to rank the relative importance of the components or the significance of FM versus BM. This experiment was carried out simply as an example that the paradigm holds in applied settings.

6.3. Disney's Principles for Animation

In order to further analyze our proposed paradigm, we compare and map the components of PV with Disney's principles of animation [5]. The goal of this analysis is to examine how the concepts of PV correspond to Disney's set of 12 principles and vice versa. It should be noted, however, that Disney's principles recount for general animation and are not limited to human motion unlike our model, which only discusses FM and BM. Table II shows the correlation between the two paradigms in human motion domain.

Many of the Disney's principles are concerned with correct presentation and preservation of animation cues as well as physical laws. As a result, they can be related to association. Principle 1, squash and stretch, is concerned with weight and volume, hence, physical characteristics. Thus, it can be related to association where correct depiction of motion cues is proposed, regardless of whether the cues belong to PTs or STs. Often regarded as the most important principle, it resonates with the first component of our paradigm. The fourth principle is solely concerned with animation techniques and notions such as volume, size, and proportions. As a result, this principle is only similar to association. Principle 5, follow through and overlapping action, suggests that some degrees of freedom of a moving body keep moving when that body comes to a stop, referring to physical kinetic laws. As this principle strictly considers physical rules, we can only relate it to association in the framework of human motion. Similar to principle 5, the sixth principle called slow in and slow out, is concerned with acceleration and decelerations of bodies, referring to physical laws yet again.

Comp. Anim. Virtual Worlds 2016; **27**:58–71 © 2015 John Wiley & Sons, Ltd.
DOI: 10.1002/cav

Table II. Mapping Disney's set of principles for animation with components of perceptual validity. A: association; CD: contextual dependency; EC: external consistency; IC: internal consistency.

	Disney principles		Perceptual validity components			
Number	Principle	Summary/implications	A	CD	IC	EC
1	Squash and stretch	Volume of squashed or stretched object is constant	✓			
2	Anticipation	Specific movements are anticipated based on physical properties; focus on an object about to be subjected to force		✓		
3	Staging	Presenting an action, mood, personality, or expression clearly	✓	✓		
4	Straight ahead action and pose to pose	Animation process: "straight ahead action" and "pose to pose"	✓			
5	Follow through and overlapping action	Parts of bodies (with degrees of freedom) will move after the body has stopped; different parts of a body can move with different rates	✓			
6	Slow in and slow out	A body needs time to accelerate and decelerate	✓			
7	Arcs	Natural actions often follow a path of a trajectory in arch format	✓			
8	Secondary action	While a character performs a main action, it can perform secondary (smaller) supporting actions			✓	✓
9	Timing	Correct timing (number of frames per action or second) results in realistic scenes	✓			
10	Exaggeration	Realism versus style: Disney preferred realism but in a bit wilder form	✓	✓		
11	Solid drawing	Animation in third dimension with weight and volume	✓			
12	Appeal	Characters being charismatic and interesting, even if not necessarily sympathetic	✓	✓		

Consequently, we map this principle to association. The seventh principle, arcs, suggests that natural motion is generally arc-like. While this property is difficult to map onto our paradigm, we can only distinctly relate it to association where naturally and correct appearing features and cues are discussed. The ninth principle, timing, suggests that correct frame rates and timing result in realistic scenes. As this law is directly in regard to preservation and correct presentation of animation content, it can be mapped to association. Principle 11, solid drawing, again emphasizes robust visualization, taking into account volume, weight, solidity, and other factors in three dimensions. As a result, similar to several other principles, this is mapped onto association.

Anticipation, which is the second principle, puts focus on bodies or objects in the scene. Naturally, this principle is developed through the events that lead to the particular scene, hence, context. Therefore, we relate this principle to contextual dependency.

The third principle called staging directly relates to association as it dictates correct and clear depiction of PTs and STs. Moreover, this principle demands the themes to be clearly displayed based on the "story," which in turn dictates the context. Therefore, the principle also related to contextual dependency.

Principle 8 is called secondary action. This principle dictates that a main action is accompanied by a series of less significant yet "supporting" actions. While the terminology for this principle does not clarify whether STs are considered a form of secondary actions, it is safe to assume that this in fact is the case. As a result, this principle captures both consistency principles namely internal consistency and external consistency. In other words, the general idea behind this principle can be regarded as action cues (regardless whether primary or secondary) being in support of one another and not contradicting each other.

Exaggeration, the 10th principle, prohibits extreme visual distortion of content. Suggesting that animation should be depicted realistically; we can conclude that preservation and presentation of cues in natural format is preferred through this principle. Thus, the principle closely relates to association.

Finally, the 12th principle called appeal suggests that characters should be charismatic and interesting, even if they are not necessarily sympathetic. Here, the concept of appeal can refer to correct and accurate content from a visual and form-related point of view, hence, association. However, it has been suggested that characters can significantly appeal to the audience based on the story line, events, decisions, and actions. Therefore, this principle relates to contextual dependency of the PV paradigm as well.

As shown previously, most of Disney's animation principles are concerned with appealing and accurate presentation and format of animation content, hence, PV's association. The proposed paradigm, however, is more general and focused on consistency of cues with one another as well as context. While PV is by no means intended to replace Disney's set of principles, we believe it can be a valuable addition to the existing set of guidelines for animators, specifically for those in the field of motion animation.

7. CONCLUSION AND FUTURE WORK

In this paper, we proposed a general paradigm, the goal of which is to provide a set of guidelines for animators employing and processing human motion (FM and BM). We suggest that taking into account the 18 elements of the paradigm can ensure PV in animated motion scenes. The model suggests that visual cues that motion features (both primary and secondary) need to be spatiotemporally and perceptually accurate. Moreover, PTs and STs need to be consistent with the context of the animation scene. Finally, the STs and PTs need to be consistent, both internally and towards one another.

Through subjective experiments, we determined the relative impacts of each element in the paradigm. It was shown that some elements and some components are more important and significant than others. For more accurate results, half of the participants were experienced with animation of human motion. A case study was developed and carried out which tested contextual dependency for both primary and STs and in both face and body domain. As expected, the significant impact of this component was demonstrated. Finally, the paradigm was compared against Disney's principles for animation and interesting parallels and conclusions were observed.

For future work, case studies on other components of the paradigm need to be conducted. The results and comparisons to the comparative impacts study provided in this paper can provide useful and interesting results. Moreover, metrics for measuring the precision of each of the elements of the model can be developed. The paradigm as a whole can then be quantified through a weighted sum of the components. Finally, studying and possibly quantifying visual quality of motion (for both themes and in both face and body) and exploring the relationship of the results with PV can lead to valuable findings.

ACKNOWLEDGEMENTS

This work was supported in part by the Natural Sciences and Engineering Council of Canada (NSERC) and Ontario Centers of Excellence (OCE).

REFERENCES

1. Etemad SA, Arya A. Modeling and transformation of 3D human motion. In *Proceedings of the 5th International Conference on Computer Graphics Theory and Applications*, Angers, 2010; 307–315.
2. Darwin C. *The Expression of the Emotions in Man and Animals*. John Murray: London, 1872.
3. Cassell J, Pelachaud C, Badler N, *et al*. Animated conversation: rule-based generation of facial expression, gesture & spoken intonation for multiple conversational agents. In *Proceedings of the 21st Annual ACM Conference on Computer Graphics and Interactive Techniques*, Orlando, 1994; 413–420.
4. Etemad SA, Arya A. Classification and translation of style and affect in human motion using RBF neural networks. *Neurocomputing* 2014; **129**: 585–595.
5. Thomas F, Johnston O. *The Illusion of Life: Disney Animation*. New York: Hyperion. Chicago, 1995.
6. Lasseter J. Principles of traditional animation applied to 3D computer animation. *ACM SIGGRAPH Computer Graphics* 1987; **21**(4): 35–44.
7. Jones CCA. *The Life and Times of an Animated Cartoonist*. Farrar, Straus & Giroux: New York, 1989.
8. Miller EF. David Hume, *essays, moral, political, and literary* (*LF ed*), 1985.
9. Alam M, Dover JS. On beauty: evolution, psychosocial considerations, and surgical enhancement. *Archives of Dermatology* 2001; **137**(6): 795–807.
10. Neff M, Fiume E. Aesthetic edits for character animation. In *Proceedings of the 2003 ACM SIGGRAPH/Eurographics Symposium on Computer Animation*, San Diego, 2003; 239–244.
11. Neff M, Fiume E. AER: aesthetic exploration and refinement for expressive character animation. In *Proceedings of the 2005 ACM SIGGRAPH/Eurographics Symposium on Computer Animation*, Los Angeles, 2005; 161–170.
12. Neff M, Fiume E. Methods for exploring expressive stance. *Graphical Models* 2006; **68**(2): 133–157.
13. Aizawa K, Kodama K, Kubota A. Producing object-based special effects by fusing multiple differently focused images. *IEEE Transactions on Circuits and Systems for Video Technology* 2000; **10**(2): 323–330.
14. Jhala A, Young MR. Cinematic visual discourse: representation, generation, and evaluation. *IEEE Transactions on Computational Intelligence and AI in Games* 2010; **2**(2): 69–81.
15. Browne C, Maire F. Evolutionary game design. *IEEE Transactions on Computational Intelligence and AI in Games* 2010; **2**(1): 1–16.
16. Colton S. Creativity versus the perception of creativity in computational systems. In *Proceedings of the AAAI Spring Symposium on Creative Systems*, Palo Alto, 2008; 14–20.
17. Pedersen C, Togelius J, Yannakakis GN. Modeling player experience for content creation. *IEEE Transactions on Computational Intelligence and AI in Games* 2010; **2**(1): 54–67.
18. Yannakakis GN, Hallam J. Real-time game adaptation for optimizing player satisfaction. *IEEE Transactions on Computational Intelligence and AI in Games* 2009; **1**(2): 121–133.

19. McGloin R, Nowak KL, Stiffano SC, Flynn GM. *The Effect of Avatar Perception on Attributions of Source and Text Credibility*. Temple University: Philidelphia, PA, 2010.
20. Reitsma PS, Pollard NS. Perceptual metrics for character animation: sensitivity to errors in ballistic motion. *ACM Transactions on Graphics* 2003; **22**(3): 537–542.
21. Ren L, Patrick A, Efros AA, Hodgins JK, Rehg JM. A data-driven approach to quantifying natural human motion. *ACM Transactions on Graphics* 2005; **24**(3): 1090–1097.
22. Tang JK, Leung H, Komura T, Shum HP. Emulating human perception of motion similarity. *Computer Animation and Virtual Worlds* 2008; **19**(3–4): 211–221.
23. O'Sullivan C, Howlett S, Morvan Y, McDonnell R, O'Conor K. Perceptually adaptive graphics. *Eurographics State of the Art Reports* 2004; **4**: 1–24.
24. Barzel R, Hughes J, Wood DN. Plausible motion simulation for computer graphics animation. In *Computer Animation and Simulation*, In *Proceedings of the Eurographics Workshop Computer Animation and Simulation*, Boulic R, Hégron G (eds). Springer, 1996; 183–197.
25. Harrison J, Rensink RA, Van De Panne M. Obscuring length changes during animated motion. *ACM Transactions on Graphics* 2004; **23**(3): 569–573.
26. Garcia M, Dingliana J, O'Sullivan C. Perceptual evaluation of cartoon physics: accuracy, attention, appeal. In *Proceedings of the 5th ACM Symposium on Applied Perception in Graphics and Visualization*, Los Angeles, 2008; 107–114.
27. Inman VT, Eberhart HD. The major determinants in normal and pathological gait. *The Journal of Bone & Joint Surgery* 1953; **3**(35): 543–558.
28. Murray MP, Drought AB, Kory RC. Walking patterns of normal men. *The Journal of Bone & Joint Surgery* 1964; **46**(2): 335–360.
29. Murray MP. Gait as a total pattern of movement: including a bibliography on gait. *American Journal of Physical Medicine & Rehabilitation* 1967; **46**(1): 290–333.
30. Napier J. The antiquity of human walking. *Scientific American* 1967; **216**(4): 56.
31. Murray MP, Kory RC, Sepic SB. Walking patterns of normal women. *Archives of Physical Medicine and Rehabilitation* 1970; **51**(11): 637.
32. Johansson G. Visual perception of biological motion and a model for its analysis. *Perception & Psychophysics* 1973; **14**(2): 201–211.
33. Barclay CD, Cutting JE, Kozlowski LT. Temporal and spatial factors in gait perception that influence gender recognition. *Perception & Psychophysics* 1978; **23**(2): 145–152.
34. Dittrich WH. Action categories and the perception of biological motion. *Perception* 1993; **22**(1): 15–22.
35. Bertenthal BI, Pinto J. Global processing of biological motions. *Psychological Science* 1994; **5**(4): 221–225.
36. Kozlowski LT, Cutting JE. Recognizing the sex of a walker from a dynamic point-light display. *Perception & Psychophysics* 1977; **21**(6): 575–580.
37. Mather G, Murdoch L. Gender discrimination in biological motion displays based on dynamic cues. *Proceedings of the Royal Society of London Series B: Biological Sciences* 1994; **258**(1353): 273–279.
38. Saunders DR, Williamson DK, Troje NF. Gaze patterns during perception of direction and gender from biological motion. *Journal of Vision* 2010; **10**(11): 9.
39. Cutting JE, Kozlowski LT. Recognizing friends by their walk: gait perception without familiarity cues. *Bulletin of the Psychonomic Society* 1977; **9**(5): 353–356.
40. Jokisch D, Daum I, Troje NF. Self recognition versus recognition of others by biological motion: viewpoint-dependent effects. *Perception* 2006; **35**: 911–920.
41. Dittrich WH, Troscianko T, Lea SE, Morgan D. Perception of emotion from dynamic point-light displays represented in dance. *Perception* 1996; **25**(6): 727–738.
42. Atkinson AP, Dittrich WH, Gemmell AJ, Young AW. Emotion perception from dynamic and static body expressions in point-light and full-light displays. *Perception* 2004; **33**: 717–746.
43. Pollick FE, Paterson HM, Bruderlin A, Sanford AJ. Perceiving affect from arm movement. *Cognition* 2001; **82**(2): B51–B61.
44. Patterson HM, Pollick FE, Sanford AJ. The role of velocity in affect discrimination. In *Proceedings of the Twenty-Third Annual Conference of the Cognitve Science Society*, Edinburgh, 2001; 756–761.
45. Roether CL, Omlor L, Christensen A, Giese MA. Critical features for the perception of emotion from gait. *Journal of Vision* 2009; **9**(6): 15.
46. Hodgins JK, O'Brien JF, Tumblin J. Perception of human motion with different geometric models. *IEEE Transactions on Visualization and Computer Graphics* 1998; **4**(4): 307–316.
47. McDonnell R, Jörg S, Hodgins JK, Newell F, O'sullivan C. Evaluating the effect of motion and body shape on the perceived sex of virtual characters. *ACM Transactions on Applied Perception* 2009; **5**(4): 20.
48. Etemad SA, Arya A, Parush A. Additivity in perception of affect from limb motion. *Neuroscience Letters* 2014; **558**: 132–136.
49. Etemad SA, Arya A, Parush A. Spatial perceptual weights of energy-related features in animation of

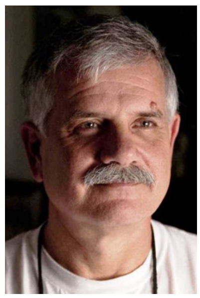
human motion. In *Proceedings of Computer Graphics International*, Ottawa, 2011; S15.
50. Blake R, Shiffrar M. Perception of human motion. *Annual Reviews of Psychology* 2007; **58**: 47–73.
51. Kleinsmith A, Bianchi-Berthouze N. Affective body expression perception and recognition: a survey. *IEEE Transactions on Affective Computing* 2013; **4**(1): 15–33.
52. Etemad SA, Payeur P, Arya A. Automatic temporal location and classification of human actions based on optical features. In *Proceedings of the 2nd IEEE International Congress on Image and Signal Processing*, Tianjin, 2009; 1–5.
53. Lee J, Chai J, Reitsma PS, Hodgins JK, Pollard NS. Interactive control of avatars animated with human motion data. *ACM Transactions on Graphics* 2002; **21**(3): 491–500.
54. Popovic Z. Editing dynamic properties of captured human motion. In *Proceedings of the IEEE International Conference on Robotics and Automation*, San Francisco, 2000; 670–675.
55. Calder AJ, Young AW. Understanding the recognition of facial identity and facial expression. *Nature Reviews Neuroscience* 2005; **6**: 641–651.
56. Ekman P, Friesen W. Facial action coding system. Consulting Psychologists Press, 1977.
57. Kshirsagar S, Magnenat-Thalmann N. A multilayer personality model. In *Proceedings of the 2nd International Symposium on Smart Graphics*, Hawthorne ACM: New York, USA, 2002; 107–115.
58. Rousseau D, Hayes-Roth B. Interacting with personality-rich characters. Report No. KSL 97, 1997; 6.
59. Egges A, Kshirsagar S, Magnenat-Thalmann N. A Model for Personality and Emotion Simulation. *Proc. Knowledge-Based Intelligent Information & Eng. Systems (KES '03)*, 2003; 453–461.
60. Pelachaud C, Bilvi M. Computational model of believable conversational agents. *Communication in Multiagent Systems* 2003; 300–317.
61. Wiggins JS, Trapnell P, Phillips N. Psychometric and geometric characteristics of the revised interpersonal adjective scales (IAS-R). *Multivariate Behavioral Research* 1998; **23**(4): 517–530.
62. Arya A, Jefferies LN, Enns JT, DiPaola S. Facial actions as visual cues for personality. *Computer Animation and Virtual Worlds* 2006; **17**(3–4): 371–382.
63. Posner J, Russell JA, Peterson BS. The circumplex model of affect: an integrative approach to affective neuroscience, cognitive development, and psychopathology. *Development and Psychopathology* 2005; **17**(3): 715–734.
64. Mehrabian A. Framework for a comprehensive description and measurement of emotional states. *Genetic, Social, and General Psychology Monographs* 1995; **121**: 339–361.
65. Tiedens LZ, Linton S. Judgment under emotional certainty and uncertainty: the effects of specific emotions on information processing. *Journal of Personality and Social Psychology* 2001; **81**(6): 973–988.
66. Ruth JA, Brunel FF, Otnes CC. Linking thoughts to feelings: investigating cognitive appraisals and consumption emotions in a mixed-emotions context. *Journal of the Academy of Marketing Science* 2002; **30**(1): 44–58.
67. Wallraven C, Breidt M, Cunningham DW, Bülthoff HH. Evaluating the perceptual realism of animated facial expressions. *ACM Transactions on Applied Perception* 2008; **4**(4): 4.
68. Pelachaud C. Modelling multimodal expression of emotion in a virtual agent. *Philosophical Transactions of the Royal Society, B: Biological Sciences* 2009; **364**(1535): 3539–3548.
69. Ekman P. Basic Emotions. In Dalgleish T, Power T (eds). *The Handbook of Cognition and Emotion*, Sussex, U.K.: John Wiley & Sons, Ltd., 1999; 45–60.
70. Ekman P, Friesen WV. *Pictures of Facial Affect*. Consulting Psychologists Press: Palo Alto, 1975.
71. Coulson M. Attributing emotion to static body postures: recognition accuracy, confusions, and viewpoint dependence. *Journal of Nonverbal Behavior* 2004; **28**(2): 117–139.
72. Calvert TW, Chapman J, Patla A. Aspects of the kinematic simulation of human movement. *IEEE Computer Graphics and Applications* 1982; **2**(9): 41–50.
73. Kovar L, Schreiner J, Gleicher M. Footskate cleanup for motion capture editing. In *Proceedings of the 2002 ACM SIGGRAPH/Eurographics Symposium on Computer Animation*, San Antonio, 2002; 97–104.
74. Yin RK. Looking at upside-down faces. *Journal of Experimental Psychology* 1969; **81**(1): 141–145.
75. Bartlett JC, Searcy J. Inversion and configuration of faces. *Cognitive Psychology* 1993; **25**(3): 281–316.
76. McKelvie SJ. Emotional expression in upside-down faces: evidence for configurational and componential processing. *British Journal of Social Psychology* 1995; **34**(3): 325–334.
77. Cutting JE. A program to generate synthetic walkers as dynamic point-light displays. *Behavior Research Methods* 1978; **10**(1): 91–94.
78. Cutting JE. Generation of synthetic male and female walkers through manipulation of a biomechanical invariant. *Perception* 1978; **7**(4): 393–405.
79. Birdwhistell RL. *Kinesics and Context: Essays on Body Motion Communication*. University of Pennsylvania Press: Philadelphia, 1970.

80. Cohn JF. Foundations of human computing: facial expression and emotion. In *Proceedings of the 8th International Conference on Multimodal Interfaces*, Banff, 2006; 233–238.
81. Pantic M, Pentland A, Nijholt A, Huang T. Human computing and machine understanding of human behavior: a survey. In Huang T, Nijholt A, Pantic M, Pentland A (eds). *Artifical Intelligence for Human Computing*. Springer, 2007; 47–71.
82. Sánchez D, Chamorro-Martınez J, Vila MA. Modelling subjectivity in visual perception of orientation for image retrieval. *Information Processing & Management* 2003; **39**(2): 251–266.
83. Eisenhauer J. Beyond bombardment: subjectivity, visual culture, and art education. *Studies in Art Education* 2006; **47**(2): 155–169.
84. Arya A, DiPaola S. Multi-space behavioural model for face-based affective social agents. *EURASIP Journal on Image and Video Processing, Special Issue on Facial Image Processing* 2007; **2007**: 048757.
85. Ekman P. Facial expression and emotion. *American Psychologist* 1993; **48**(4): 384.

AUTHORS' BIOGRAPHIES:

S. Ali Etemad received his BSc from Isfahan University of Technology (Iran) in 2007. He received his MASc and PhD in Electrical and Computer Engineering from the Department of Systems and Computer Engineering, Carleton University (Canada) in 2009 and 2014, respectively. His PhD research was on machine learning, pattern recognition, and computer vision, focused on human motion analysis for interactive multimedia and HCI applications. During his PhD, he worked as a contract instructor, departmental TA mentor, teaching assistant, and research assistant. He is a recipient of several scholarships and awards including the Ontario Graduate Scholarship. His PhD research was nominated for multiple awards. Ali is currently the Head of Machine Intelligence and HCI at GestureLogic, a wearable tech company in Ottawa. He is also an adjunct professor with the School of Information Technology at Carleton University. He is an editorial board member/reviewer for multiple journals including IEEE Access. He has been a technical committee member and a session chair for various conferences.

Ali Arya received his Bachelor's degree in Electrical Engineering from Tehran Poly-technique, Iran, in 1989 and his PhD in Computer Engineering from the University of British Columbia, Canada, in 2003. He has more than 10 years of industry experience as a project manager and a software engineer, has worked as an instructor and a researcher in the University of British Columbia and Simon Fraser University in Vancouver, Canada, and joined the School of Information Technology, Carleton University, Ottawa, Canada, in 2006 where he is currently an associate professor of Interactive Multimedia and Design. Ali's major research areas are computer graphics and animation, multimedia systems, human–computer interaction, virtual worlds and collaborative environments, artificial intelligence, and digital art. He is a senior member of IEEE, on the editorial board of International Journal of Computer Games Technology and Journal of Systemics and Informatics, and a member of technical and program committees of many conferences in the area of multimedia systems. His research has been funded by NSERC, SSHRC, OCE, and industry partners.



Avi Parush is an associate professor in Psychology at Carleton University, Ottawa, Canada. He received his PhD in Experimental–Cognitive Psychology from McGill University, Montreal, Canada, in 1984. His professional career in human factors engineering (HFE), usability engineering, and human–computer interaction (HCI) spans over 25 years. He is the founding editor in chief of the Journal of Usability Studies.

Steve DiPaola received a BSc degree in Computer Science from State University of New York at Stony Brook, NY, in 1981 and an MA degree in Computer Graphics from New York Institute of Technology, NY, in 1991. He is currently an associate professor in Simon Fraser University's newest school—the School of Interactive Arts and Technology in Surrey, BC, Canada, which actively combines technology, science, and the arts using online and collaborative methods. There, he directs of the iVizLab (ivizlab.sfu.ca), which conducts research on "Socially-based Interactive Visualization." He has research interests in human-centered design, computer graphics and animation, and interactive systems. He had published (papers and book chapters) extensively in the area of character and avatar-based 3D virtual communication technologies and has given presentations worldwide. DiPaola has been a teacher and a researcher at such institutions as Stanford University and the Computer Graphics Lab at New York Institute of Technology.